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The Isomer State of HF-178(16+) Studing: Theoretical Investigation.

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The Isomer State of HF-178(16+) Studing: Theoretical Investigation.

Abstract.

In this paper total experimental and theoretical data about Hf-178 levels are presented: levels of Hf-178 and decay, electromagnetic momentum of Hf-178, ratio B(E2), B(E3), B(E4) and others ratio and parameters has been calculated in Nilson modell. The results of calculation are presented, and comparised with experimental data and others calculations.

Introduction.

The scheme of long-lifetime isomer g-laser seen to be the most natural and easy for experimental layont. Such may was alredy proposel in the first aplication by L.A.Rivlin [1]. Using long-lifetime nuclei as initial object for -laser creation was also suggested by other authors [2,3]. Excited radioactive nuclei in long-liftime isomer state are radiochemically separated from nuclei in ground state.

Then during a period, much lower than the liftime, a crystel is grown of radioactive isomer by one of the know techniques, e.g. Bridgman technicue of crystallization from melt. In such crystel the inversion condition holds practically always. The it is necessary to cool the crystal to low temperatures to obtain the conditions for Mossbauer effect observation, and the crystal begins to emit. But sinc one fails to preserve the line of natural width, the stimulated emission will not occur.

And therefore all activity on creation of long-lifetime isomer g-laser was directed to search of methods for Mossbauer radiation linewidth reduction to its natural value.

Line broadening may be uniform and non-uniform. The uniform line

broadening arises e.g. at vibrations of atoms in the crystal lattice, or electron spin fluctuations in paramagnetic crystals. Similar reasons broadening can be eliminated or minimized by the process freering e.g. by deep cooling of the sample to the temperature much lower than 1 K. It is quite possible to realise such conditions at modern level of physics and engineering. But there is a lot of technical obstacles on this way, and the problem seens to become purely experimental. However, theoretical studies, especially, in our opinion, elucidation of the mechanism of interaction of gamma-quanta with the nucleus for each separate specific level, studying of the degre of collectivity of various levels excitation processes and studies of their structure, should localize and reduce the number of the most urgent problems.

The longest-lifetime isomer, know at present is ^{178}Hf, having been found in [4] with the energy of 2446.0 (16+, K=16). In the same paper the scheme of this isomeric state decay was proposed [6]. The structure of ^{178}Hf level was studied by considering decay of two ^{178}Ta isomers and in (n,g) reaction. ^{178}Hf nucleus is a very interesting, because it is an even- even nucleus. There is a wide variety of data available on the studies of the levels of this nucleus. The studies of this nucleus seem to be very interesting, since the inkrest to the problem of long-liftime isomer g-laser is still strong, what was demonstrated at Garalas-95 schol [5-9].

Our view point on this problem consist in studying the nature of the level, the transitions between which are important for creating inverse population of ^{178m2}Hf isomer by calculating probabilities of the transitions between the levels, using various models. It is the level nature which determines the model choice. Since, as noted above, the higher levels are a mixture of a great amount of states, as a rule, of all the states of the band, it seems important to construct realistic bases for the studies of these states and the choice of the corresponding interaction potentials.

1.WIBRATIVE-ROTATIVE MODELL AND TOTAL HAMILTONIAN FOR DEFORMED NUCLEI.

It is known, that in the region of axial-symmetric deformed nuclei for lowly situated exitation states the projection of spine I into the axis of symmetry of nucleus K is being a good quantum number [10]. Together with this position, it is interesting to find out in what conditions the non-maintainance of the number K is begin and how this transition is going through.

With the increase of energy exitation the density of nucleus levels grows greatly and some levels are changing into the combinations of different configurations with the varied numbers of quasi-partical [11]. Howerer, if in such exiations it were possible to neglect the powers of Coriolis the levels would form the rotation bands being characterized by a quantum number within the systems of axial symmetry [10].

From the results of the analysis on data of neutrons capture by nuclei it is possible to conclude, that for the neutron resonance states connected with the energy excitations of nuclea, near to the energy of connection of neuron B_n. The possible dimensions of the projection K by the given meaning are practically equally possible [10-11]. The possible mechanism causing the non-maintainance of the K is the Coriolis's mixing.

The Corriolis's interaction leads to the connection of inner and collective rotation of deformed nucleus and mixing states with different K and within strong Coriolis's combination the resulting state of the nucleus J^{π} will present the superposition of states I^{π} K, with all possible at the given meanings of the K. In the frameworks of the abovementioned issues certain interest presents the study of K-isomer stimulation of depended nuclea in the reactions of in-elastic scattering gamma-quanta.

For the nuclea with constant deformation of interaction is:

$$\hat{H}_{int} = \sum_i f(r_i) \sum_\mu \alpha^*_{2\mu} Y^{(i)}_{2\mu} \ldots \qquad (1.1)$$

between individual nuclons and collective vifeations is rather tight and the use of perturbation theory is not positive any more. Therefore the connection with the deformed core of nucleus must be considered precisely. This leads to the model of films for deformed nuclea, that is to the monopartitative films in the deformed potential. The full Hamiltonian has a general structure:

$$\hat{H} = \hat{H}_{coll} + \hat{H}_{sp} + \hat{H}_{int} \qquad (1.2),$$

where

$$\hat{H}_{sp} = \sum_i \left\{ \hat{T}_i + V\left(r_i, \hat{l}_i, \hat{s}_i\right) \right\} \qquad (1.3)$$

$\hat{H}_{sp}$ - Hamiltonian of shell modell, T_i - kinetic energy, V_i - potential of shell modell for i partical.

Howerer, the collective Hamiltonian now presents the correspondent collective Hamiltonian of the deformed nucleus and namely vibrative-rotative Hamiltonian. The used projected modell is illustated on figure 1, which shows how two nuclons move around the deformed core white the core itself according to the vibrative-rotative modell can vibrate and rotate.

It is understandatle that the task of such kind may be solved with the use of other models as well being lased on the modell of assymetric rotator. For the low situated collective exitations the both models give almost the same results, we prefer the dynamic approach of the vibrative-rotative modell.

The Hamiltonian of the vibrative-rotative modell consists of rotative moment of the core $\hat{M}$. The total angular moment of the system $\hat{I}$ consists of the moment of the core and the moment of appeared partical $\hat{j}$, $\hat{j} = \sum_{\nu=1,2,...} \hat{j}_\nu$,where $\hat{j}_\nu$ - angular moments of individual partical.

Substituting $\hat{M} = \hat{I} - \hat{j}$ into the vibrative-rotative Hamiltonian (1.2) it is easy to get H_{coll} for deformed nuclea, which preserve some additional parts over core. The result has the following form:

$$\hat{H} = \hat{H}_{rot} + \hat{H}_{vib} + \hat{H}_{vibrot} \tag{1.4}$$

where

$$\hat{H}_{rot} = \frac{(\hat{I} - \hat{j})^2 h^2 - (\hat{I}_3 - \hat{j}_3) h^2}{2\mathcal{J}_0} + \frac{(\hat{I} - \hat{j})^2 h^2}{16B\eta^2}; \tag{1.4 a}$$

$$\hat{H}_{vib} = \frac{h^2}{2B}\left[\frac{d^2}{d\xi^2} + \frac{1}{2}\frac{d^2}{d\eta^2}\right] + \frac{1}{2}C_0\xi^2 + C_0\eta^2 - \frac{h^2}{16B\eta^2}; \tag{1.4 b}$$

$$\hat{H}_{vibrot} = \frac{\left(\hat{I} - \hat{J}\right)^2 \mathrm{h}^2 - \left(\hat{I}_3 - J_3\right)\mathrm{h}^2}{2\mathcal{J}_0}\left[2\frac{\eta^2}{\beta_0^2} - 2\frac{\xi}{\beta_0} + 3\frac{\xi^2}{\beta_0^2}\right] + $$
$$+\frac{\left(\hat{I}_+ - \hat{J}_+\right)^2 \mathrm{h}^2 - \left(\hat{I}_- - J_-\right)\mathrm{h}^2}{4\mathcal{J}_0}\left[2\sqrt{6}\frac{\xi\eta}{\beta_0^2} - \frac{2}{3}\sqrt{6}\frac{\eta}{\beta_0}\right] \quad . \qquad (1.4\ \mathrm{c})$$

and the element of volume in space of collective coordinates $d\tau = d\Omega d\xi d\eta$.

It is interesting to mention that the prediction of film model for deformed nuclea concerning different monopartitative levels are almost true. Most of the predicted stimulated levels are found in experiment even if their energy is in compatible with the theory. Spins of the ground states are well explained in the frames of this model. Howerer, the theoretical predictions are lased on the precise meaning of nucleus deformation which must be formed of the data of meanings B (E2) for transition within the limits of the main band. Deformation being obtained this way is always connected with experimental mistakes and one-partical spectrum may be approximated only within the limits of these.

If the Nilsson's levels are set up one can try to count the other features of deformed nuclea using knowledge of the correspondent monopartitative wave functions. For example, one canon to predict the possibilities E1, M1, E2 - transition.

2. CORIOLISIS INTERACTION FOR DEFORMED NUCLEI.

Let us consider the hamiltonian of perturbation H' in the form:

$$\hat{H}' = \frac{h^2}{2\mathcal{J}_0}\hat{j}^2 - \frac{h^2}{2\mathcal{J}_0}\left[\hat{I}_+\hat{j}_- + \hat{I}'_-\hat{j}_+ + 2\hat{I}_3\hat{j}_3\right] +$$

$$\frac{h^2}{2\mathcal{J}_0}\left[\hat{I}^2 - \hat{I}_3^2 + \hat{j}^2 - \hat{j}_3^2 + \hat{I}_+\hat{j}_- - \hat{I}_-\hat{j}_+\right]\left[\frac{2\eta^2}{\beta_0^2} - 2\frac{\xi}{\beta_0} + 3\frac{\xi^2}{\beta_0^2}\right] + \tag{2.1}$$

$$+\frac{h^2}{4\mathcal{J}_0}\left[\hat{I}_+^2 + \hat{I}_-^2 + \hat{j}_+^2 - \hat{j}_-^2 - 2(\hat{I}_+\hat{j}_+ - \hat{I}_-\hat{j}_-)\right]\left[2\sqrt{6}\frac{\xi\eta}{\beta_0^2} - \frac{2}{3}\sqrt{6}\frac{\eta}{\beta_0}\right] -$$

$$-M\varpi^2 r^2\left[\xi Y_{20} + \eta\left(Y_{22} + Y_{2-2}\right)\right]$$

One of the most important members in H is Coriolisis interaction :

$$\hat{H}_{coriolis} = h^2 / 2\mathcal{J}_0(\hat{I}_+\hat{j}_- + \hat{I}_-\hat{j}_+ + 2\hat{I}_3\hat{j}_3) = -\left(h^2 / \mathcal{J}_0\right)\left(\hat{I}\cdot\hat{j}\right) \tag{2.2}$$

Matrix elements of this expression are easily calculated with the help of wavefunctions:

$$\left\langle IMK'\Omega' n\, n_{\beta}\alpha \middle| \hat{H}_{coriolis} \middle| IMK\Omega n_z n_{\beta}\alpha \right\rangle =$$

$$= \frac{h^2}{2\mathcal{J}_0}\sum_j C_{j\Omega'}^{(\alpha)*} C_{j\Omega}^{(\alpha)}\left\{\left[\delta_{K'K-I}\delta_{\Omega'\Omega-1} + (-1)^{I+\frac{1}{2}}(-1)^{j-1/2}\delta_{K'-(K-1)}\delta_{\Omega'-(\Omega-1)}\right]\left[(I+K)(I-K+1)\times\right.\right.$$

$$\left.\left.\times(j+\Omega)(j-\Omega+1)\right]^{1/2}\right\} + \left[\delta_{K'K+I}\delta_{\Omega'\Omega+1} + (-1)^{I+\frac{1}{2}}(-1)^{j-1/2}\delta_{K'-(K+1)}\delta_{\Omega'-(\Omega+1)}\right]\times \tag{2.3}$$

$$\times\left[(I-K)(I+K+1)(j-\Omega)(j+\Omega+1)\right]^{1/2}\Big\} - \frac{h^2}{2\mathcal{J}_0}2K\Omega\delta_{K'K}\delta_{\Omega'\Omega}$$

$$\hat{I}_{\chi}\hat{I}_{\lambda} - \hat{I}_{\lambda}\hat{I}_{\chi} = -i\hat{I}_{\chi\times\lambda} \tag{2.4 a}$$

$$\hat{J}_\chi \hat{J}_\lambda' - \hat{J}_\lambda' \hat{J}_\chi = \hat{J}_{\chi\times\lambda} \qquad (2.4\ b)$$

$$\hat{J}_\chi I_\lambda' - I_\lambda' \hat{J} = 0 \qquad (2.4\ c)$$

The commutational proportion was used here for operators I_v, J_v, which lead to matrix elements:

$$\left\langle IMK\middle|\hat{I}_\pm\middle|IMK\pm1\right\rangle = \sqrt{(I\mp K)(I\pm K+1)} \qquad (2.5)$$

$$\left\langle j\Omega\middle|\hat{j}_\mp\middle|j\Omega\pm1\right\rangle = \sqrt{(j\mp\Omega)(j\pm\Omega+1)} \qquad (2.6)$$

The dependence on corner moment I in the example is found only in that part which is proportional to the member in brackets. It contributes to diagonal matrix elements with K′ = K and Ω′= Ω only for band with K = 1/2. This matrix element is usually written like :

$$\langle IM\tfrac{1}{2}\tfrac{1}{2}n_z n_\rho\alpha|\hat{H}_{coriolis}|IM\tfrac{1}{2}\tfrac{1}{2}n_z n_\rho\alpha\rangle = -\frac{h^2}{2\mathcal{J}_0}\sum_j C^{(\alpha)*}_{j\Omega}C^{(\alpha)}_{j\Omega}\left\{(-1)^{(I+\frac{1}{2})}(-1)^{(j-\frac{1}{2})}(I+\frac{1}{2})(j+\frac{1}{2})\right\} -$$

$$\frac{h^2}{4\mathcal{J}_0} = \frac{h^2}{2\mathcal{J}_0}(-1)^{(I+\frac{1}{2})}(I+\frac{1}{2})a - \frac{h^2}{4\mathcal{J}_0}, \qquad (2.7)$$

where

$$a = \sum_j(-1)^{j-\frac{1}{2}}(j+\frac{1}{2})\left|C^{(\alpha)}_{j1/2}\right|^2 \qquad (2.8)$$

The so called parameter of solution - a.

This name it got because of the correspondence to partitative break of connection of monopartitative and rotative movements.

Considering the Coriolis's member in the first range of perturbation theory is the following expression:

$$E_{IK\Omega n_2\alpha} = \mathcal{E}_{\alpha\Omega} + (I(I+1) - (K-\Omega)^2\frac{1}{2}\varepsilon + \left(\frac{1}{2}|K-\Omega| + 1 + 2n_2\right)E_\gamma +$$
$$+\left(n_0 + \frac{1}{2}\right)E_\beta - a\left[(-1)^{I+\frac{1}{2}}\left(I + \frac{1}{2}\right)\right]\frac{1}{2}\varepsilon\delta_{K\frac{1}{2}} - 2K\Omega\frac{\varepsilon}{2} \qquad (2.9)$$

The influence of Coriolis's forses on the bands with K′= 1/2 may be very strong. In the considerable meanings of parameter the order of levels in the rotative band may be changed.

For a=0 levels are situated according to the rule *I(I+1)*. In the considerable positive or negative meanings a order of levels is becoming quite different.

In general sense the hamiltonian $\hat{H}$or mixes 2 rotative bands for which ΔK= ±1. It is obvious, that this effect will be small (maximum) if nonperturbed bands are greatly divided an energy. Howerer, if the connection of the part with ostov is weak, these lands are overlapping greatly and the correction from the side of Coriolis's forses is important. In this case it is possible to get the analytical expression which describes the influence of Coriolis's powers on the own energy of too baqnds, by means of simple diagonalisation of matrix 2×2 the corresponding solution are equation:

$$\begin{vmatrix} E_{IK\Omega n_0 n_2\alpha} - E & \langle IK\Omega n_2 n_0\alpha|\hat{H}_{coriolis}|IK+1\Omega+1n_2 n_0\alpha\rangle \\ \langle IK+1\Omega+1n_2 n_0\alpha|\hat{H}_{coriolis}|IK\Omega n_2 n_0\alpha\rangle & E_{IK+1\Omega+1n_2 n_0\alpha} - E \end{vmatrix} = 0 \qquad (2.10)$$

where

$$E_{\pm}\left(IK\Omega n_2 n_0 \alpha\right) = \frac{1}{2}\left\{E_{IK\Omega n_2 n_0 \alpha} + E_{IK+1\Omega+1 n_2 n_0 \alpha} \pm\right.$$

$$\left.\pm\Delta E\left[1 + 4\left|\frac{\left\langle IK+1\Omega+1 n_2 n_0 \alpha\right| \hat{H}_{coriolis} \left| IK\Omega n_2 n_0 \alpha\right\rangle}{\Delta E}\right|^2\right]^{1/2}\right\} \qquad (2.11)$$

the matrix elements being involved into this formulae are solved from the expression (1) and may be written in more simple form:

$$\left\langle IMK+1\Omega+1 n_2 n_0 \alpha\right| \hat{H}_{coriolis} \left| IMK\Omega n_2 n_0 \alpha\right\rangle = A_K[(I-K)(I+K+1)]^{1/2} \qquad (2.12)$$

where

$$A_K = -\frac{1}{2}\varepsilon\sum_j C^{(\alpha)*}_{jK+1} C^{(\alpha)}_{jK}[(j-K)(j+K+1)]^{1/2} \qquad (2.13)$$

It is apparent that K′ is not a good quantitative number any more even if the ostov still possesses aximal symmetry. Only in case when the part is connected considerably with the ostov, number ΔB is becoming increased and K will be approximated by good quantitative number.

3. NILSON SHELL MODELL AND PROBABILITY RATIO CALCULATING.

In considerably deformed nuclei one can differentiate monopartitative passages which are connected with the change of inner wave function X_n and collective passages which leave the inner monopartitative structure untouched. Within the collective passages which do not touch φ_{coll} but only change the rotative state of the system D_α .

The differentiation of movement in nucleus on collective and inner correspond to prediction that the wave pencion being the solution of wave equation for the nucleus has the following form of expression:

$$\Psi = X\,\varphi_{coll} D_\alpha \qquad (3.1)$$

where X - corresponds to inner movement of nuclons, which may be expressed using the notion of independent movement of parts in fixed non-special field. Ψ describes the rotation of nucleus concerning its equilibrical form, and D_α -presents the collective rotative movement of system as a whole [11].

For calculatind $B(\lambda, I \to I')$ we are using following expression:

$$B(\lambda, I \to I') = \sum_{\mu M'} \left| \langle \Omega', I'K'M' | \mathfrak{M}''(\lambda,\mu) | \Omega, IKM \rangle \right|^2 \qquad (3.2)$$

$$T(\lambda) = \frac{8\pi(\lambda+1)}{\lambda[(2\lambda+1)!!]^2} \frac{1}{\mathrm{h}} \left(\frac{\omega}{C}\right)^{2\lambda+1} B(\lambda) \qquad (3.3)$$

$$\mathfrak{M}''(\lambda,\mu) = \sum_{\nu} \mathcal{D}^{\lambda}_{\mu\nu}(\theta_i)\, \mathfrak{M}'(\lambda,\nu) \qquad (3.4)$$

$$B(\lambda, I \to I') = |\langle I\lambda KK' - K | I\lambda I'K' \rangle \int \chi'^{+}_{\Omega'} \mathfrak{M}(\lambda, K'-K) \chi_\Omega d\tau +$$
$$\langle I\lambda K - K' - K | I\lambda I' - K' \rangle \int [(-)^{I'-j'} \chi_{-\Omega'}]^{+} \times \mathfrak{M}(\lambda, -K'-K) \chi_\Omega d\tau|^2 \qquad (3.5)$$

$$\int \mathcal{D}\, I'^{+}_{M'K'} \mathcal{D}^{\lambda}_{\mu\lambda} \mathcal{D}^{I}_{MK}\, d\Omega^3 = \frac{8\pi^2}{2I'+1} \langle I\lambda M\mu | I\lambda I'M' \rangle \langle I\lambda K\nu | I\lambda I'K' \rangle \qquad (3.6)$$

$$\int Y^{+}_{I'\Lambda'} Y_{\lambda\nu} Y_{I\Lambda}\, d\Omega^2 = \sqrt{\frac{(2I+1)(2\lambda+1)}{4\pi(2I'+1)}} \langle I\lambda I\Lambda\nu | I\lambda I'\Lambda' \rangle \langle I\lambda 00 | I\lambda I'0 \rangle \qquad (3.7)$$

$$\mathbf{1}\cdot\left(\nabla \mathbf{r}^{\lambda} Y_{\lambda\nu}\right) = \sqrt{\frac{2\lambda+1}{2\lambda-1}}\Big[\sqrt{\lambda^2-\nu^2}\, l_z r^{\lambda-1} Y_{\lambda-1\nu} + \frac{1}{2}\sqrt{(\lambda-\nu)(\lambda-\nu-1)}\times$$
$$\times\, l_- r^{\lambda-1} Y_{\lambda-1\nu+1} - \frac{1}{2}\sqrt{(\lambda+\nu)(\lambda+\nu-1)}\, l_+ r^{\lambda-1} Y_{\lambda-1\nu-1}\Big] \qquad (3.8)$$

$$l_+ = l_x + il_y, \qquad l_- = l_x - il_y \qquad (3.8\ a)$$

$$B(E\lambda, I\to I') = e^2\left(1+(-)^{\lambda}\frac{Z}{A^{\lambda}}\right)^2\left(\frac{\mathrm{h}}{M\omega_0}\right)^{\lambda}\frac{2\lambda+1}{4\pi}\times$$
$$\times\ \left|\langle I\lambda KK'-K|I\lambda I'K'\rangle + b_{E\lambda}(-)^{I'+K'}\langle I\lambda K\ -K'\ -K\,|\,I\lambda I'\ -K'\rangle\right|^2 G^2_{E\lambda}, \qquad (3.9)$$

$$b_{E\lambda} = \frac{(-)^{K'+1/2+l}}{G_{El}}\left\{\sum_{l'l}\langle N'l'|r^{\lambda}|Nl\rangle\sqrt{\frac{2l+1}{2l'+1}}\langle l\lambda 00|l\lambda l'0\rangle\times\right.$$
$$\times\sum_{\Lambda'\Lambda\Sigma'\Sigma}\delta_{-\Sigma',\Sigma}\, a_{l'\Lambda'} a_{l\Lambda}\langle l\lambda\Lambda\ -K'\ -K|\,l\lambda l'\ -\Lambda'\rangle, \qquad (3.9\ a)$$

$$G_{E\lambda} = \sum_{l'l}\langle N'l'|r^{\lambda}|Nl\rangle\sqrt{\frac{2l+1}{2l'+1}}\langle l\lambda 00|\,l\lambda l'0\rangle\times\sum_{\Lambda'\Lambda\Sigma'\Sigma}\delta_{\Sigma',\Sigma}\, a_{l'\Lambda'} a_{l\Lambda}\langle l\lambda\Lambda K'\ -K|\,l\lambda l'\Lambda'\rangle. \qquad (3.9\ b)$$

$$B(M\lambda, I\to I') = \left(\frac{1\mathrm{h}}{2Mc}\right)\left(\frac{\mathrm{h}}{M\omega_0}\right)^{\lambda-1}\frac{1}{4}\frac{2\lambda+1}{4\pi}\left|\langle I\lambda KK'-K|I\lambda I'K'\rangle + \right.$$
$$b_{M\lambda}(-)^{I'+K'}\langle I\lambda K-K'-K\,|\,I\lambda I'-K'\rangle\left|G^2_{M\lambda},\right. \qquad (3.10)$$

$$\begin{aligned}
b_{M\lambda} = {} & \frac{(-)^{K'+1/2+l'}}{G_{M\lambda}} \sum_{l'l} \langle N'l' | r^{\lambda-1} | N l \rangle \langle l\lambda -100 | l\lambda -1 l' 0 \rangle \sqrt{\frac{2l+1}{2l'+1}} \times \\
& \times \sum_{\Lambda'\Lambda\Sigma'\Sigma} a_{l'\Lambda'} a_{l\Lambda} \Big\{ g_s \Big[A(q) \delta_{-\Sigma',E} (-)^{\Sigma-1/2} \langle l\lambda -1\Lambda q | l\lambda -1 l' -\Lambda' \rangle + \\
& + B(q) \delta_{\Sigma',1/2} \delta_{\Sigma,1/2} \langle l\lambda -1\Lambda q+1 | l\lambda -1 l' -\Lambda' \rangle - \\
& - C(q) \delta_{\Sigma',-1/2} \delta_{\Sigma,-1/2} \langle l\lambda -1\Lambda q-1 | l\lambda -1 l' -\Lambda' \rangle + \\
& + \frac{2}{\lambda+1} g\rho_{-\Sigma',\Sigma} \Big[A(q)(-2\Lambda') \langle l\lambda -1\Lambda q | l\lambda -1 l' -\Lambda' \rangle + \\
& + B(q) \sqrt{(l'+\Lambda')(l'-\Lambda'+1)} \langle l\lambda -1\Lambda q+1 | l\lambda -1 l' -\Lambda'+1 \rangle - \\
& - C(q) \sqrt{(l'-\Lambda')(l'+\Lambda'+1)} \langle l\lambda -1\Lambda q-1 | l\lambda -1 l' -\Lambda'+1 \rangle \Big] \Big\}
\end{aligned} \tag{3.10 a}$$

$$\begin{aligned}
G_{M\lambda} = {} & \sum_{l'l} \langle N'l' | r^{\lambda-1} | N l \rangle \langle l\lambda -100 | l\lambda -1 l' 0 \rangle \times \\
& \times \sqrt{\frac{2l+1}{2l'+1}} \sum_{\Lambda'\Lambda\Sigma'\Sigma} a_{l'\Lambda'} a_{l\Lambda} \Big\{ g_s \Big[A(k) \delta_{\Sigma',E} (-)^{\Sigma-1/2} \langle l\lambda -1\Lambda k | l\lambda -1 l' \Lambda' \rangle + \\
& + B(k) \delta_{\Sigma',-1/2} \delta_{\Sigma,1/2} \langle l\lambda -1\Lambda k+1 | l\lambda -1 l' \Lambda' \rangle - \\
& - C(k) \delta_{\Sigma',1/2} \delta_{\Sigma,-1/2} \langle l\lambda -1\Lambda k-1 | l\lambda -1 l' \Lambda' \rangle + \\
& + \frac{2}{\lambda+1} g\rho_{\Sigma',\Sigma} \Big[A(k) 2\Lambda' \langle l\lambda -1\Lambda k | l\lambda -1 l' \Lambda' \rangle + \\
& + B(k) \sqrt{(l'-\Lambda')(l'+\Lambda'+1)} \langle l\lambda -1\Lambda k+1 | l\lambda -1 l' \Lambda'+1 \rangle - \\
& - C(k) \sqrt{(l'+\Lambda')(l'-\Lambda'+1)} \langle l\lambda -1\Lambda k-1 | l\lambda -1 l' \Lambda'-1 \rangle \Big] \Big\},
\end{aligned} \tag{3.10 b}$$

$$A(\nu) = \sqrt{\lambda^2 - \nu^2}, \tag{3.11 a}$$

$$B(\nu) = \sqrt{(\lambda - \nu)(\lambda - \nu - 1)}, \tag{3.11 b}$$

$$C(\nu) = \sqrt{(\lambda + \nu)(\lambda + \nu - 1)}, \tag{3.11 c}$$

$$k = K' - K, \tag{3.11 d}$$

$$q = -K' - K. \tag{3.11 e}$$

$$G_{M1} = (g_\Omega - g_R) 2\Omega \tag{3.11 f}$$

$$b_0 = -\frac{(-)^l}{g_\Omega - g_R} \Big\{ (g_s - g_R) \sum_l a_{l0}^2 + 2(g_l - g_R) \sum_l \sqrt{l(l+1)}\, a_{l0} a_{l1} \Big\} \tag{3.12}$$

$$B_0(\mathrm{M1}) = \frac{(3)}{64\pi}\left(\frac{1\mathrm{h}}{2\mathrm{M}c}\right)^2 \frac{2\mathrm{I}'+1}{\mathrm{I}'+1} G_0^2\left|1 + b_0(-)^{\mathrm{I}'-1/2}\right|^2 \tag{3.13}$$

$$2b_0 G_0 = G_0 - 2(g_l - g_R)a + g_s - 2g_l + g_R \tag{3.14}$$

$$G_0 = 3\mu - a(g_l - g_R) + \frac{1}{2} g_s + g_l - 2g_R \tag{3.15}$$

and

$$b_0 = -\frac{1}{2G_0}\left[3\mu + a(g_l - g_R) + \frac{1}{2} g_s - d_l - g_R\right] \tag{3.16}$$

The matrix element:

$$\langle \mathrm{N}'l' | \mathbf{r}^\lambda | \mathrm{N}l \rangle = \left[\frac{\Gamma(n+l)\Gamma(n'+l')}{\Gamma(n+t-\nu+l)\Gamma(n'+t'-\nu'+l')}\right]^{1/2} \nu'!\,\nu!\times \tag{3.17}$$

$$\sum_\sigma \frac{\Gamma(t+\sigma+l)}{\sigma!(n-\sigma)!(n'-\sigma)!(\sigma+\nu-n)!(\sigma+\nu'-n')!}$$

where

$$n = \frac{1}{2}(\mathrm{N} - l), \tag{3.17 a}$$

$$n' = \frac{1}{2}(\mathrm{N}' - l'), \tag{3.17 b}$$

$$\nu = \frac{1}{2}(l - l' + \lambda), \tag{3.17 c}$$

$$\nu' = \frac{1}{2}(l - l' + \lambda), \tag{3.17 d}$$

$$t = \frac{1}{2}(l + l' + \lambda + 1) \tag{3.17 e}$$

and where

$$n \geq \sigma \geq n - \nu \tag{3.18 a}$$

$$n' \geq \sigma \geq n' - \nu' \tag{3.18 b}$$

$$l + \lambda \geq l' \geq l - \lambda, \tag{3.18 c}$$

$$\mathrm{N} + \lambda \geq \mathrm{N}' \geq -\lambda \tag{3.18 d}$$

4. THE REZULTS OF CALCULATION RATIO Â(Eλ) .

For example, few ratio B (Eλ) and few B (Eλ) are presented:

	exp.	theor.
$\dfrac{2+0(1276.7)\to 2+0(93.2)}{0+0(1199.4)\to 2+0(93.2)}$	> 2.44 [33]	3.2
$\dfrac{2+0(1276.7)\to 2+0(93.2)}{2+0(1276.7)\to 0+0(0.0)}$	= 10.0(25) [33]	12.5
$\dfrac{2+0(1276.7)\to 4+0(306.6)}{2+0(1199.4)\to 2+0(93.2)}$	= 1.13[33]	1.5
$\dfrac{4+0(1450.4)\to 4+0(306.6)}{4+0(450.4)\to 2+0(93.2)}$	> 42.8[33]	45.0

B(E2) in Hf-178

Transition	exp.	Ref.	theor.
0+0(0)→2+0(1276.7) =	0.002(1)	[21]	0.03
	0.024(2)	[28]	
	0.018(7)	[16]	
0+0(0)→2+2(1276.7) =	0.100(8)	[21]	0.05
	0.113(12)	[32]	
	0.017(3)	[28]	
	0.015(4)	[16]	
0 + 0(0)→2+0(1496.4) =	0.01	[21]	0.02
	0.017(10)	[28]	
	0.013(2)	[16]	

X(E0/E2) in Hf-178

Transition	exp.	Ref.	theor.
0+0(1199.4)→0+0(0) =	0.02(6)	[33]	0.18

0.155(11) [50]
0.160(9) [32]

2+0(1276.7)→2+0(93.2) = 0.026(4) [33] 1.4
0.13<X<0.23 [50]
1.35(18) [50]
1.56(15) [32]
4+0(1450.4)→4+0(306.6)= 0.15(7) [33]
0.19

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